



Memorandum

To: Mike P. DiBenedetto
From: Brian V. Hayduk *BVH*
Date: 11/17/2003
Subject: King Street Area Sub-transmission Study—Recommended 23kV Supply Improvements.

SUMMARY

The King Street Area Sub-transmission Study was completed in September, 2003. The study was performed to address a number of thermal overload and voltage performance issues on the 23 kV sub-transmission system supplied from King Street #18 substation in Groveland, Massachusetts. This memorandum documents improvements required by the summer of 2004.

The area was studied as recently as 1997, however actual load growth has significantly exceeded all projections. As a result, a number of normal and contingency loading issues currently exist on the sub-transmission system. In 2003, major area sub-transmission problems consisted of the following:

- Normal thermal overload at a number of points on the sub-transmission system during peak loading levels.
- Low voltage at the extremities of the sub-transmission system on peak, during normal conditions.
- Contingency thermal overload occurring when one sub-transmission line trips and the remaining line is required to carry its normal peak load plus the load that automatically transfers over from the interrupted line. Voltage on the remaining line sags to unacceptable levels (with possible voltage stability concerns).

A number of operating practices involving reconfiguration of supply, blocking of automatic substation transfer above prescribed load levels and the use of diesel generation to peak load shave were implemented in 2003 to avoid these problems. These practices will remain in effect until improvements can be made as recommended herein.

The recommended sub-transmission plan (Plan #1) addresses the normal and contingency voltage issues as well as contingency overload problems through the installation of:

- A 19.2 MVar, 23 kV substation capacitor bank at Ipswich Municipal Substation.
- Installation of a new 23 kV line (2319) from King Street #18 substation to the 2373 bifurcation at Mill Street Junction.
- Installation of a new 23 kV line (2403) from King Street #18 substation to the 2396 bifurcation.
- Various 23 kV line upgrades as needed.
- Various 23 kV pole top capacitor upgrades as needed.

The total cost for this plan is \$4.5M in 2003 dollars. Later this year Transmission Planning will conduct a long-term study to determine the larger area need and most viable method for transmission expansion beyond the time and scope of this study. No further expansion of the sub-transmission system is prudent

beyond the improvements recommended herein until the long-term transmission study is complete to ensure that all future work is in-line with transmission expansion plans.

STATUS OF EXISTING SUB-TRANSMISSION SYSTEM

During the course of the study, a number of problems occurring during normal and contingency system conditions were identified. Refer to Figure #1 for detail on the configuration of the 23 kV system.

An underground sub-transmission cable on the 2373 line experiences an overload during peak normal load conditions. One overhead sub-transmission line (2373) is projected to be overloaded during peak normal load conditions in 2004. A number of sub-transmission lines supplied out of King Street #18 substation experience contingency overloads and/or low voltage problems. Analysis indicates that reactive losses due to high loading and long line length could possibly cause voltage instability during contingency on the 2367, 2373, 2377 and 2394 lines.

A number of interim operating practices have been established to mitigate these problems and were in place during 2003. A summary of these problems is listed in Table #1 with the percentage of 2003 load level that these problems occur and the interim actions taken for mitigation.

Table #1: Summary of existing thermal overload and/or voltage problems.

<u>Circuit</u>	<u>Problem</u>	<u>% of 2003 peak load</u>	<u>Interim Action</u>
2373	NORMAL OVERLOAD—cable into Newburyport above SN rating	91%	Transfer Newbury 60L3 feeder to the 2373 line
2377	CONTINGENCY LOW VOLTAGE—upon loss of 2396 line	78%	Block auto-transfers at W. Newbury #47, Hillside #66
2396	CONTINGENCY OVERLOAD AND LOW VOLTAGE—upon loss of 2377 line	78%	Block auto-transfers at W. Newbury #47, Hillside #66
2367	CONTINGENCY OVERLOAD AND/OR LOW VOLTAGE—upon loss of 2373, 2377 or 2394 lines	82%	Block auto-transfer at Beach Road #7
2373	CONTINGENCY OVERLOAD AND/OR LOW VOLTAGE—upon loss of 2367 or 2394 lines	85%	Block auto-transfer at E. Boxford #33
		86%	Block auto-transfer at Newbury #60
		72%	Run generation at Ipswich Municipal
2394	CONTINGENCY OVERLOAD AND LOW VOLTAGE—upon loss of 2373 line	80%	Parallel both UG cables into Newburyport
		86%	Block auto-transfer at Newbury #60
		72%	Run generation at Ipswich Municipal

Normal overload on the 2356 is being addressed by the ongoing Haverhill Area Study. Normal overload on the 2373 underground cable was addressed by expediting the third cable between the High Street Terminal and Newburyport #36 Substation. The third cable was recommended in the *Newburyport Distribution Study* and is projected to be in service by the summer of 2004. Contingency overload of the 2367 for loss of the 2394 line was addressed by reconfiguring the supply to East Boxford #33 and Topsfield #26 substations. Interim actions needed to mitigate problems not addressed prior to summer 2003 will remain in effect until the recommendations from this study are implemented.

PLAN DEVELOPMENT

Options for permanently addressing contingency thermal overload and voltage performance issues on the 2377 and 2396 lines will be addressed outside of this report and are part of a longer-term plan. Until then however, interim actions listed above will be needed to limit load automatically transferred onto one line following loss of the other. To reduce the likelihood of a line outage on the 2396 line, it is recommended to build a new 23 kV line (2403) from a new position at King Street #18 substation to the point where the 2396 line bifurcates. The new line would tap onto the portion of the 2396 line feeding toward Groveland, thereby reducing the amount of exposure on the 2396 to faults.

Two options for addressing normal thermal overload issues on the 2373 line and contingency thermal overload and voltage issues on the 2367, 2373 and 2394 lines were reviewed. Plan #1 (recommended) involves:

- Installation of a 23 kV capacitor bank consisting of four 4.8 MVAR stages at Ipswich Municipal Substation in 2004. The capacitor is needed for both normal and contingency voltage support.
- Addition of a new 23 kV line (2319) between King Street #18 and the "Mill Street Junction" required by 2004 to split the 2373 bifurcation thereby avoiding thermal overload and improving the voltage profile across the 23 kV system. Installation of the 2319 line to split the 2373 bifurcation will also reduce the number of customers exposed to momentary outages.
- 23 kV line reconductoring on the 2394 and 2373 is recommended as needed to avoid thermal overload.
- Upgrade of six 1.8 MVAR pole top capacitor banks to 2.7 MVAR.

The cost for this work is estimated to be \$4.5M in 2003 dollars. Figure #2 identifies locations where upgrades are recommended under Plan #1.

An alternative to the recommended plan—Plan #2—was also studied to address issues described previously. The alternative option involves extending the new 2319 line beyond the "Mill Street Junction" along the 2373/2394 right-of-way to either a new 23 kV switching station to be located at a suitable site in Rowley or all the way to Ipswich. The new line would relieve load from the existing 2373 and 2394 lines thereby eliminating thermal overload and voltage performance problems. Extension of the 2319 line would be done in place of installing the 23 kV substation capacitor bank at Ipswich. 23 kV line reconductoring work on the 2373 and the 2394 would still be needed to avoid contingency thermal overload issues on the existing lines because the 2319 line would not be able to be completed prior to the summer of 2004. As a result the alternative plan was determined to be significantly more costly than the recommended plan. Estimated cost for the alternative plan was \$7.8M in 2003 dollars. The alternative plan also has greater permitting complexity and, in turn, a lower probability of timely completion as compared with the recommended plan. Figure #3 identifies locations where upgrades are recommended under Plan #2.

CONCLUSION & RECOMMENDATION

Plan #1 is the recommended plan and involves construction of a substation capacitor bank at Ipswich Municipal substation, construction of two new 23 kV lines, reconductoring of existing 23 kV lines and pole top capacitor upgrades. The results of the study have been presented to North and Granite Division Engineering and Operations personnel and there are no unresolved issues. Project Data Sheets will be issued all recommendations shortly

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Figure #1: Existing King Street 23 kV sub-transmission system.

King Street Area One-Line—EXISTING

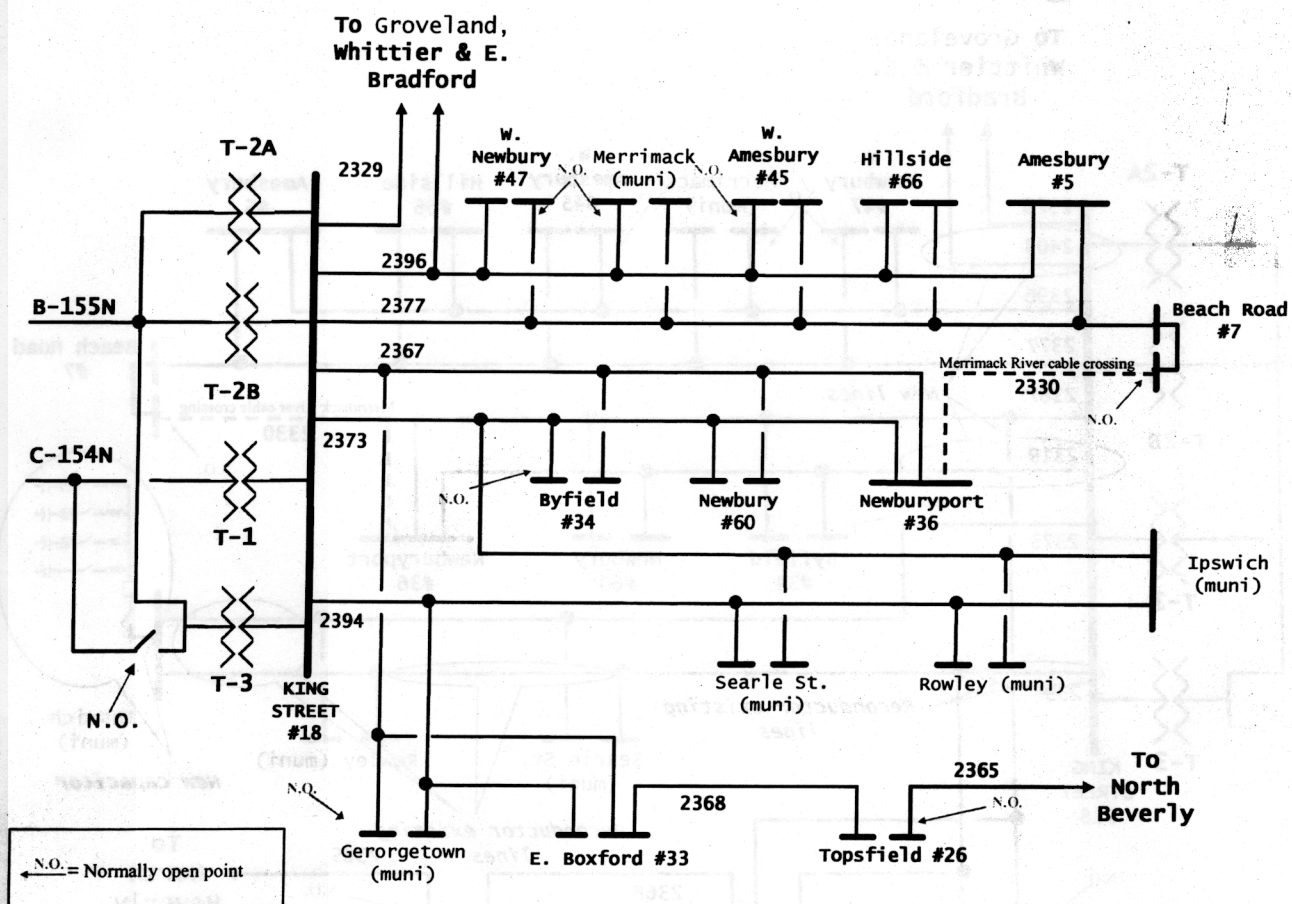


Figure #2: Recommended improvements to King Street 23 kV sub-transmission system (Plan #1).

King Street Area One-Line—PLAN #1

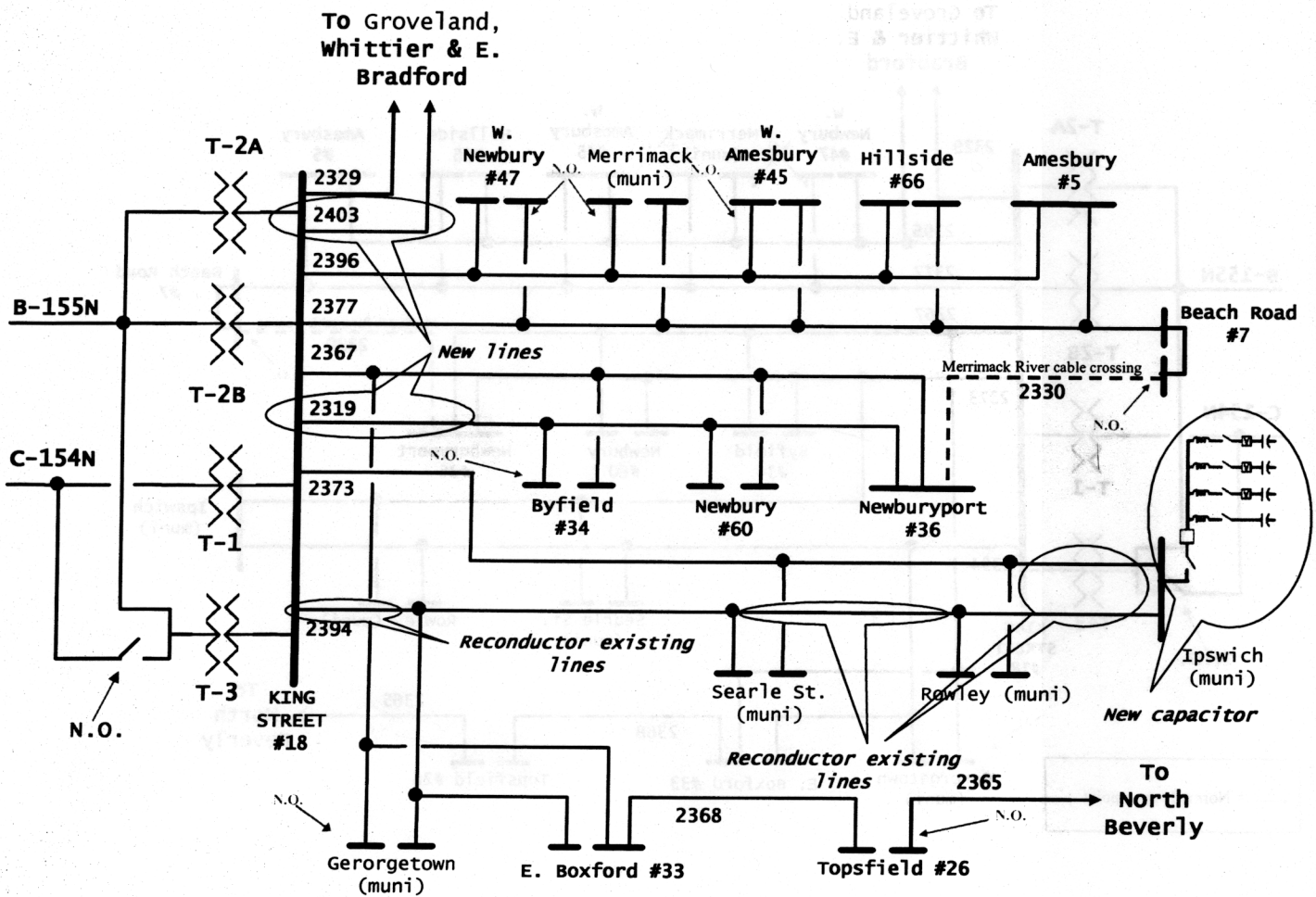


Figure #3: Alternative improvements to King Street 23 kV sub-transmission system (Plan #2).

King Street Area One-Line—PLAN #2

